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Determination of the effect of performing a simple task over a prolonged period on the rate of energy expenditure.

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Thesis
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DETERMINATION OF THE EFFECT OF PERFORMING A SIMPLE TASK OVER A PROLONGED PERIOD ON THE RATE OF ENERGY EXPENDITURE

A Thesis

Submitted to the Faculty

of

Purdue University

by

John Henry Behl

In Partial Fulfillment of the

Requirements for the Degree

of

Master of Science in Industrial Engineering

June, 1951

A Simulation Study on the Role of Energy Dissipation
Mechanisms on the Behavior of Vibrating Cable Cars

A Thesis

Submitted to the Faculty

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John Henry Bond

In Partial Fulfillment of the

Requirements for the Degree

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I want to express my sincere appreciation to Professor S. Tilles for his guidance and assistance in organizing this thesis, and to Dr. V. L. Anderson for his assistance in the statistical analysis. I also want to thank the nine students who gave up six hours of their time to provide the data for this thesis, and my wife for helping make it a finished product.

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I wish to express my sincere appreciation to Professor E. Willis for his guidance and assistance in organizing this thesis, and to Dr. F. R. Jameson for his assistance in the mathematical analysis. I also wish to thank the students who gave up six hours of their time to provide the data for this thesis, and my wife for helping make it a finished product.

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ABSTRACT

Although there have been numerous experiments involving the use of metabolic equipment for measuring energy expenditure during the performance of a simple task, none of these have been conducted over a prolonged continuous period. This thesis involved taking three simple tasks and finding the effect on energy expenditure of performing these tasks for sixty-four minutes without interruption. The tasks used were:

1. A seventeen inch transfer of small steel balls at a tempo of 96 one way beats per minute of a metronome.
2. A twenty-five inch motion for each arm between two points at a tempo of 160 one way beats per minute of a metronome.
3. Pedaling a bicycle, with chain disconnected, at a tempo of 138 one way beats per minute of a metronome.

The results of this thesis indicate that the energy expenditure appears to rise rapidly at the beginning of the simple task and does not change significantly for at least a period of time of sixty-four minutes.

Although there have been numerous experiments involving the use of metabolic equipment for measuring energy expenditure during the performance of a single task, none of these have been conducted over a prolonged continuous period. This thesis involved taking three simple tasks and finding the effect on energy expenditure of performing those tasks for sixty-four minutes without interruption. The tasks used were:

1. A seventeen inch treadle at small steel bells at a tempo of 88 one way beats per minute of a metronome.
2. Pedaling a bicycle, with chain disconnected, at a tempo of 132 one way beats per minute of a metronome.
3. A twenty-five inch motion for each arm between two points at a tempo of 120 one way beats per minute of a metronome.

The results of this thesis indicate that the energy expenditure appears to rise rapidly at the beginning of the single task and does not change significantly for at least a period of time of sixty-four minutes.

DETERMINATION OF THE EFFECT OF PERFORMING A SIMPLE TASK OVER A PROLONGED PERIOD ON THE RATE OF ENERGY EXPENDITURE

INTRODUCTION AND PURPOSE

This is another in the series of theses conducted in the Metabolic Laboratory of Purdue University and employing the use of the Sanborn EIS Metabolism Tester. During the years since 1907 there have been many experiments conducted involving the measurement of energy expenditure by use of metabolic studies of various tasks, but none of these studies have been conducted for a prolonged continuous period. This thesis is undertaken to determine just what effect a prolonged period of performance of a simple task will have on energy expenditure. A bi-product of the research will be a statement of the length of time, up to the time limit used, that each of the simple tasks employed can be accomplished before a significant change in energy expenditure is noted.

A Technical Problem on the Basis of Energy Requirements

INTRODUCTION AND THEORY

This is another in the series of theses submitted in the Metabolic Laboratory of Purdue University and employing the use of the Bunsen Tri Metabolism Chart. During the years since 1907 there have been many experiments conducted involving the measurement of energy expenditure by use of metabolic stoves of various kinds, but none of these studies have been conducted for a prolonged continuous period. This thesis is undertaken to determine just what effect a prolonged period of performance of a simple task will have on energy expenditure. A by-product of the research will be a statement of the length of time, up to the time limit used, that each of the simple tasks employed can be accomplished before a significant change in energy expenditure is noted.

PROCEDURE

Due to the length of time required to test each student and the number of theses being conducted on the metabolic equipment at the time of this study, it was decided to limit the testing to nine male students. These students were selected at random from motion and time study classes at Purdue University. No attempt was made to select students of the same age, height or weight, as can be seen in Table 1.

The limitations explained in the previous paragraph are also the reasons that the time of testing was not limited to the early morning period. To eliminate the possibility of the order of tests having an effect on the results, the tests were conducted in accordance with Table 2. Only one test per student was conducted on any particular day.

Prior to each test the student to be tested was allowed to become familiar with the procedure in performing the task. On the day a particular test was to be performed the student came to the laboratory and spent the first thirty minutes resting in a reclined position. Just prior to the end of the thirty minute rest period the student got into position for the test to be performed; the nose clamp was adjusted and the mouthpiece shield inserted. With the beginning of the test as "zero" time, the following schedule was adhered to for all the tests:

Due to the length of time required to test each student and the number of tissue typing conducted on the particular equipment at the time of this study, it was decided to limit the testing to nine male students. These students were selected at random from medium and tone study classes at Purdue University. An attempt was made to select students of the same age, height or weight, as can be seen in Table I.

The limitations explained in the previous paragraph are also the reasons that the time of testing was confined to the early morning period. To eliminate the possibility of the urge of taste having an effect on the results, the tests were conducted in accordance with Table 3. Only one test per student was conducted on any particular day.

Prior to each test the student to be tested was allowed to become familiar with the procedure in positioning the tuner. On the day a particular test was to be performed the student came to the laboratory and spent the first thirty minutes resting in a reclined position. Just prior to the end of the thirty minute rest period the student was taken position for the test to be performed; the nose clamp was adjusted and the mouthpiece gently inserted. With the beginning of the test as "zero" time, the following measures were entered to for all the tests:

TABLE 1

STUDENT	AGE	HEIGHT	WEIGHT
1	32	5'-9"	161
2	29	5'-11"	133
3	29	5'-6"	162
4	25	6'-0"	190
5	24	5'-11"	176
6	21	5'-7"	154
7	24	6'-2"	200
8	29	5'-9"	142
9	21	6'-0"	155

TABLE I

TABLE 2

SEQUENCE OF TESTS

STUDENT	1st TEST	2nd TEST	3rd TEST
1	1	2	3
2	3	1	2
3	1	3	2
4	3	2	1
5	2	1	3
6	2	3	1
7	1	2	3
8	3	2	1
9	2	1	3

TABLE 8

RECORDS OF TESTS

Column 1	Column 2	Column 3	Column 4
1	8	1	9
2	7	9	6
3	9	1	2
4	2	3	1
5	1	5	8
6	2	3	1
7	5	1	8
8	8	3	7
9	7	8	3

Time	Elapsed Time	Action
00-01	1 minute	Operator breathed room air while performing task.
01-05	4 minutes	Without knowledge of the operator, the metabolic equipment was turned on and a record run was made.
05-10	5 minutes	Same as 00-01 minutes.
10-14	4 minutes	Same as 01-05 minutes.
14-20	6 minutes	Same as 00-01 minutes.
20-24	4 minutes	Same as 01-05 minutes.
24-30	6 minutes	Same as 00-01 minutes.
30-34	4 minutes	Same as 01-05 minutes.
34-40	6 minutes	Same as 00-01 minutes.
40-44	4 minutes	Same as 01-05 minutes.
44-50	6 minutes	Same as 00-01 minutes.
50-54	4 minutes	Same as 01-05 minutes.
54-60	6 minutes	Same as 00-01 minutes.
60-64	4 minutes	Same as 01-05 minutes.

Test 1 consisted of a seventeen inch transfer, by the right hand, of small steel balls at a tempo of 96 one way beats per minute of a metronome. This task was rated at 110 percent of standard pace by comparison with a multi-image step film.[1] It is the exact task used by J. A. Marks and W. D. Surface in their work.[2] See Figure 1.

[1] Mundel, M. E., Motion and Time Study Principles and Practice, Prentice-Hall Inc., New York, 1950, p. 324.

Time	Elapsed Time	Action
00-01	1 minute	Character produced upon air entry to Detection room.
01-06	6 minutes	Without knowledge of the operator, the aeropulse equipment was turned on and a record run was made.
06-10	3 minutes	Same as 00-01 minutes.
10-14	4 minutes	Same as 01-06 minutes.
14-20	6 minutes	Same as 00-01 minutes.
20-24	4 minutes	Same as 01-06 minutes.
24-30	6 minutes	Same as 00-01 minutes.
30-34	4 minutes	Same as 01-06 minutes.
34-40	6 minutes	Same as 00-01 minutes.
40-44	4 minutes	Same as 01-06 minutes.
44-50	6 minutes	Same as 00-01 minutes.
50-54	4 minutes	Same as 01-06 minutes.
54-00	6 minutes	Same as 00-01 minutes.
00-04	4 minutes	Same as 01-06 minutes.

Test I consisted of a seventeen hour furnace, by the Tiffin Pump, of small steel balls at a temp of 19 cps and 110 percent of standard pace by comparison with a multi-beats per minute of a metronome. Tiffin pump was tested at single step rate.[1] It is the exact test used by J. W. Barnes

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[1] Wendel, H. J., Motion and Time Study Principles and Practice, Prentice-Hall Inc., New York, 1950, p. 214.

ted W. I. Burgess in their work, See Figure I.

FIGURE 1

POSITIONS FOR TEST 1

[2]Marks, J. A., The Effect of Praise and Reprimand on Workers' Energy Expenditure, Master of Science Thesis, Purdue University, Lafayette, Indiana, 1951.

Surface, W. D., The Effect of Music on the Metabolic Rate of Workers, Master of Science Thesis, Purdue University, Lafayette, Indiana, 1951.

Test 2 consisted of a twenty-five inch motion for each arm between points on the table edge at a tempo of 160 one way beats per minute of a metronome. This task was rated at 135 percent of standard pace. This task is similiar to one of the tasks used by S. Tilles in his work.[3] See Figure 2.

[3]Tilles, S., An Investigation of the Suitability of the Sanborn EIS Metabolism Tester to Basic Time Study Experimentation, Master of Science Thesis, Purdue University, Lafayette, Indiana, 1949.

Test 3 consisted of pedaling a bicycle, with the chain to the back wheel disconnected, at a tempo of 138 one way beats per minute of a metronome. This task was rated at 120 percent of standard pace. See Figure 3.

Test 2 consisted of pedaling a bicycle, with the cable to the back wheel disconnected, at a tempo of 120 one way beats per minute of a metronome. This task was rated at 120 percent of standard pace. See Figure 2.

Test 3 consisted of a twenty-five inch vertical fly ball batted by a baseball player on the public edge at a tempo of 120 one way beats per minute of a metronome. This task was rated at 120 percent of standard pace. This task is similar to one of the tasks used by S. Tillyer in his work.[3] See Figure 3.

---

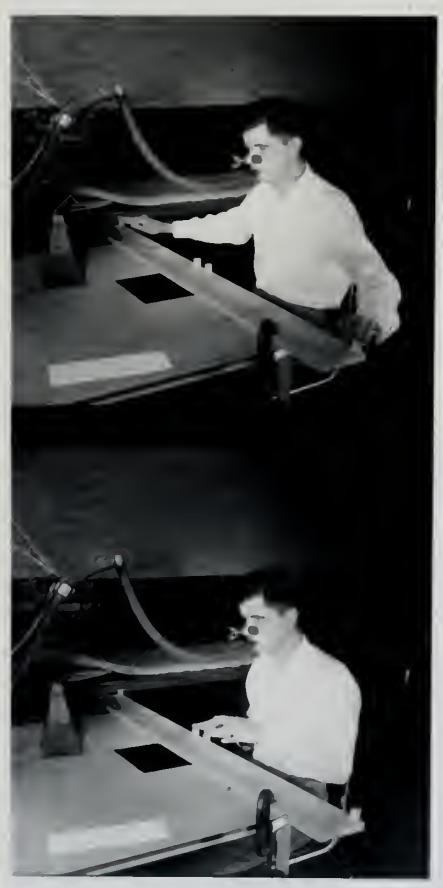
[3] Tillyer, S., An Investigation of the Dependability of the Baseball XIX Metropolitan Leaguer to Begin Time Study Expectation, Bureau of Science Theory, Purdue University, Lafayette, Indiana, 1949.

---

[2] Barnes, R. M., The Effect of Pedals and Repetitive or Monotonous Movements, Bureau of Science Theory, Purdue University, Lafayette, Indiana, 1937.

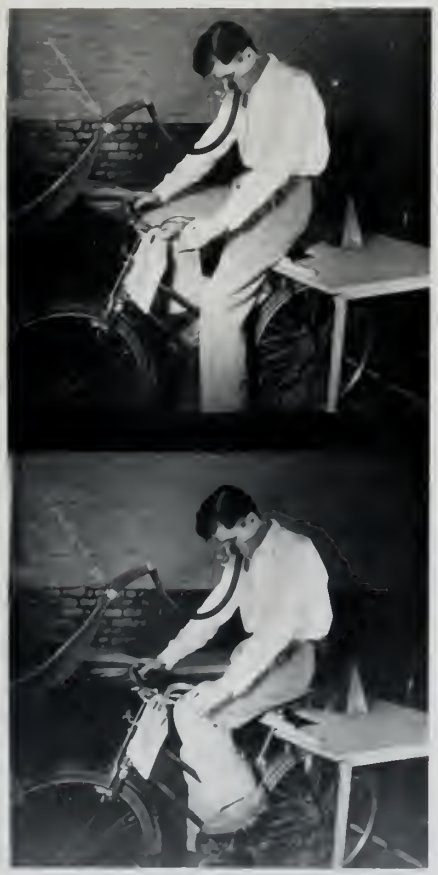
Barnes, R. M., The Effect of Pedals and Repetitive or Monotonous Movements, Bureau of Science Theory, Purdue University, Lafayette, Indiana, 1937.

FIGURE 2



POSITIONS FOR TEST 2

FIGURE 3



POSITIONS FOR TEST 3

RESULTS AND CONCLUSION

The method of least squares was used to calculate the slopes of the charts obtained from the metabolic tester. Tables 3 to 11 contain the results for the various students. Tables 12 to 17 present the information for all students for each test, and also include the values of "t" obtained by the Student "t" technique of statistical analysis. Appendix A shows an example of how these "t" values were calculated. The Student "t" technique indicated that for each of the three tests there was no significant difference, at the five percent level, between the base reading for the test and the readings taken at any other time during the test. In the analysis, all the values obtained for student 8 were omitted as that student was a controlled breather and his charts did not have sufficient points to give a consistent value. The information for student 7, test 2, was also eliminated due to the fact that the nose clamp became loose during the base run and caused the obviously false readings.

The conclusion arrived at is that for a relatively simple task similiar to those used in this thesis the energy expenditure rises rapidly during the first minute of performing the task and does not change significantly for at least sixty-four minutes. Since all the previous experiments in the Purdue Metabolic Laboratory have been based on the fact

Results and Conclusion

The method of least squares was used to calculate the slopes of the charts obtained from the metabolic tester. Tables 8 to 11 contain the results for the various subjects. Tables 12 to 17 present the information for all students for each test, and also include the values of "E" obtained by the student "t" technique of statistical analysis. Appendix A shows an example of how these "t" values were integrated. The Student "t" technique indicated that for each of the five test levels, between the base reading for the test and the readings taken at any other time during the test. In the analysis, all the values obtained for student 6 were omitted as that student was a confirmed breather and his charts did not have sufficient points to give a consistent value. The information for student 7, test 3, was also eliminated due to the fact that the nose clamp became loose during the base reading thus causing the obviously false reading.

The conclusion arrived at is that for a relatively simple test similar to those used in this thesis the energy expenditure rises rapidly during the first minute of exercising the test and does not change significantly for at least sixty-four minutes. Since all the precautions enumerated in the Puritan Metropolis Inspectory have been heeded on the test

that the energy expenditure did remain constant, this thesis helps to verify that fact. It also points out that rest periods need not be used once the task has commenced if all readings can be obtained in a one hour period.

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TABLE 3

STUDENT NUMBER 1

TEST	TIME(MIN)	TEMP.	SLOPE	% OF 01-05 MIN.
1	01-05	20 C	.430	100
	10-14	23 C	.434	101
	20-24	24 C	.450	105
	30-34	24 C	.459	107
	40-44	25 C	.549	128
	50-54	26 C	.474	110
	60-64	26 C	.460	107
2	01-05	26 C	.602	100
	10-14	27 C	.612	102
	20-24	27 C	.600	100
	30-34	28 C	.622	103
	40-44	28 C	.596	99
	50-54	27 C	.637	106
	60-64	28 C	.621	103
3	01-05	23 C	.734	100
	10-14	24 C	.736	100
	20-24	24 C	.660	90
	30-34	25 C	.628	86
	40-44	25 C	.622	85
	50-54	26 C	.668	91
	60-64	27 C	.674	92

	TEST 1	TEST 2	TEST 3
DATE	3/13/51	4/4/51	4/12/51
START TIME	2:38 P.M.	3:53 P.M.	4:35 P.M.
BAROMETER	28.90"	29.25"	28.70"

TABLE 3

STUDENT SCORES I

TEST	TIME(MIN)	TEMP.	SCORE	% OF 01-05 MIN.
1	01-05	80 C	.430	100
	10-14	82 C	.634	102
	20-24	24 C	.650	108
	30-34	24 C	.609	107
	40-44	25 C	.069	178
	50-54	26 C	.674	110
	60-64	16 C	.600	107
2	01-05	86 C	.602	100
	10-14	27 C	.612	108
	20-24	27 C	.000	100
	30-34	25 C	.622	103
	40-44	28 C	.518	84
	50-54	27 C	.537	104
	60-64	22 C	.661	105
3	01-05	30 C	.734	100
	10-14	24 C	.738	100
	20-24	24 C	.665	90
	30-34	23 C	.632	86
	40-44	20 C	.622	84
	50-54	24 C	.665	91
	60-64	27 C	.674	92

	TEST 1	TEST 2	TEST 3
DATE	5/14/61	4/4/61	4/18/61
START TIME	8:35 P.M.	3:00 P.M.	4:05 P.M.
BAROMETER	28.60"	27.83"	28.70"

TABLE 4

STUDENT NUMBER 2

TEST	TIME(MIN)	TEMP.	SLOPE	% OF 01-05 MIN.
1	01-05	27 C	.458	100
	10-14	28 C	.475	104
	20-24	29 C	.451	98
	30-34	29 C	.492	107
	40-44	30 C	.432	94
	50-54	31 C	.442	97
	60-64	31 C	.450	98
2	01-05	26 C	.634	100
	10-14	27 C	.619	98
	20-24	27 C	.589	93
	30-34	27 C	.580	91
	40-44	27 C	.590	93
	50-54	27 C	.625	99
	60-64	27 C	.535	84
3	01-05	26 C	.531	100
	10-14	26 C	.619	117
	20-24	27 C	.609	115
	30-34	27 C	.584	110
	40-44	27 C	.549	103
	50-54	28 C	.562	106
	60-64	28 C	.528	99

	TEST 1	TEST 2	TEST 3
DATE	3/23/51	4/4/51	3/19/51
START TIME	4:20 P.M.	9:19 P.M.	4:00 P.M.
BAROMETER	29.37"	29.29"	29.37"

TABLE 4

TEST	TIME(MIN)	TEMP.	BLOCK	% OF 01-05 MIN.
1	01-05	27 C	.456	100
	10-14	25 C	.477	104
	20-24	29 C	.491	99
	30-34	25 C	.473	107
	40-44	30 C	.468	94
	50-54	31 C	.445	97
	60-64	31 C	.460	88
2	01-05	28 C	.454	100
	10-14	27 C	.419	94
	20-24	27 C	.384	93
	30-34	27 C	.360	91
	40-44	27 C	.370	96
	50-54	27 C	.389	95
	60-64	27 C	.359	97
3	01-05	26 C	.581	100
	10-14	26 C	.619	117
	20-24	27 C	.609	118
	30-34	27 C	.584	110
	40-44	27 C	.549	109
	50-54	28 C	.562	106
	60-64	28 C	.528	95

	TEST 1	TEST 2	TEST 3
DATE	5/20/21	6/4/21	5/19/21
START TIME	4:00 P.M.	3:30 P.M.	4:00 P.M.
BAROMETER	29.87"	29.82"	29.87"

TABLE 5

STUDENT NUMBER 3

TEST	TIME(MIN)	TEMP.	SLOPE	% OF 01-05 MIN.
1	01-05	26 C	.423	100
	10-14	27 C	.438	104
	20-24	28 C	.409	97
	30-34	28 C	.392	93
	40-44	28 C	.421	100
	50-54	28 C	.414	98
	60-64	29 C	.425	100
2	01-05	22 C	.575	100
	10-14	23 C	.519	90
	20-24	25 C	.492	86
	30-34	25 C	.528	92
	40-44	26 C	.496	86
	50-54	26 C	.551	96
	60-64	26 C	.475	83
3	01-05	25 C	.718	100
	10-14	25 C	.703	98
	20-24	27 C	.669	93
	30-34	26 C	.689	96
	40-44	28 C	.689	96
	50-54	29 C	.767	107
	60-64	29 C	.839	117

	TEST 1	TEST 2	TEST 3
DATE	4/5/51	4/27/51	4/23/51
START TIME	2:45 P.M.	12:33 P.M.	12:00 P.M.
BAROMETER	29.33"	29.47"	29.62"

Table 6

Report Number 4

Type	Yrs/Mos	Test.	Effect	% of 01-05 Std.
1	01-05	36 0	.853	100
	10-14	37 0	.839	104
	20-24	45 0	.459	87
	30-34	48 0	.345	93
	40-44	38 0	.451	109
	50-54	25 0	.414	98
	60-64	25 0	.480	100
2	01-05	36 0	.847	100
	10-14	35 0	.819	90
	20-24	25 0	.486	86
	30-34	33 0	.352	81
	40-44	36 0	.498	86
	50-54	28 0	.851	96
	60-64	26 0	.470	85
3	01-05	25 0	.718	100
	10-14	29 0	.703	99
	20-24	27 0	.909	91
	30-34	29 0	.000	96
	40-44	28 0	.688	98
	50-54	28 0	.769	107
	60-64	24 0	.859	119

Test 1 Test 2 Test 3

Date 4\8\01 4\27\01 4\27\01
Start Time 1:05 P.M. 12:38 P.M. 12:00 P.M.
Barometric 29.08" 29.47" 29.45"

TABLE 6

STUDENT NUMBER 4

TEST	TIME(MIN)	TEMP.	SLOPE	% OF 01-05 MIN.
1	01-05	29 C	.439	100
	10-14	30 C	.502	114
	20-24	30 C	.449	102
	30-34	30 C	.446	102
	40-44	31 C	.458	104
	50-54	31 C	.402	92
	60-64	32 C	.426	97
2	01-05	30 C	.666	100
	10-14	30 C	.735	110
	20-24	29 C	.638	96
	30-34	29 C	.625	94
	40-44	30 C	.600	90
	50-54	29 C	.629	94
	60-64	31 C	.640	96
3	01-05	22 C	.618	100
	10-14	22 C	.810	131
	20-24	24 C	.708	115
	30-34	25 C	.688	111
	40-44	25 C	.687	111
	50-54	25 C	.747	121
	60-64	24 C	.787	127

	TEST 1	TEST 2	TEST 3
DATE	4/27/51	4/25/51	4/9/51
START TIME	4:00 P.M.	4:07 P.M.	10:45 A.M.
BAROMETER	29.49"	29.24"	28.96"

Table 6

Different Number 4

Year	Time(sec)	Time.	Place	6 Cr 01-63 Pts.
1	01-03	36 C	.459	100
	10-14	30 C	.502	114
	40-54	30 C	.543	109
	30-34	30 C	.646	102
	40-44	21 C	.680	104
	50-54	31 C	.403	98
	60-64	34 C	.420	97
2	01-05	30 C	.564	100
	10-14	30 C	.738	110
	20-24	30 C	.659	96
	50-54	23 C	.622	94
	40-44	30 C	.000	90
	50-54	30 C	.623	91
	60-64	21 C	.640	76
6	01-05	25 C	.614	100
	10-14	25 C	.810	121
	20-24	24 C	.709	116
	50-56	25 C	.600	111
	40-44	29 C	.607	111
	50-54	25 C	.749	131
	60-64	24 C	.759	127

	Test 1	Test 2	Test 3
Date	4/02/23	4/09/81	4/9/12
Event Time	4:00 P.M.	4:07 P.M.	10:45 A.M.
Barometer	29.65"	29.14"	28.30"

TABLE 7

STUDENT NUMBER 5

TEST	TIME(MIN)	TEMP.	SLOPE	% OF 01-05 MIN.
1	01-05	24 C	.482	100
	10-14	25 C	.521	108
	20-24	25 C	.484	100
	30-34	26 C	.489	101
	40-44	27 C	.539	112
	50-54	27 C	.471	98
	60-64	27 C	.443	92
2	01-05	22 C	.709	100
	10-14	25 C	.682	96
	20-24	25 C	.639	90
	30-34	26 C	.633	89
	40-44	26 C	.584	82
	50-54	27 C	.602	85
	60-64	27 C	.677	95
3	01-05	22 C	.651	100
	10-14	24 C	.756	116
	20-24	24 C	.690	106
	30-34	23 C	.689	106
	40-44	24 C	.656	101
	50-54	24 C	.599	92
	60-64	24 C	.625	96

	TEST 1	TEST 2	TEST 3
DATE	4/12/51	4/9/51	4/19/51
START TIME	12:50 P.M.	1:00 P.M.	12:48 P.M.
BAROMETER	28.70"	28.94"	29.36"

TABLE V

STUDENT RECORDS 8

ITEM	[illegible]	[illegible]	[illegible]	[illegible]
1	01-05	24 0	.049	100
	10-14	25 0	.321	108
	15-19	25 0	.491	100
	20-24	25 0	.529	102
	25-29	26 0	.537	112
	30-34	27 0	.471	92
	35-39	27 0	.419	92
2	01-05	22 0	.709	100
	10-14	23 0	.522	96
	15-19	25 0	.529	90
	20-24	25 0	.522	89
	25-29	26 0	.096	86
	30-34	27 0	.509	86
	35-39	27 0	.077	96
3	00-05	20 0	.082	100
	10-14	21 0	.709	112
	15-19	24 0	.990	109
	20-24	25 0	.029	106
	25-29	25 0	.929	101
	30-34	24 0	.099	92
	35-39	24 0	.529	94

	TEST 1	TEST 2	TEST 3
DATE	6/12/51	6/2/51	6/12/51
START TIME	12:30 P.M.	1:00 P.M.	12:45 P.M.
[illegible]	88.75°	80.94°	69.80°

TABLE 8

STUDENT NUMBER 6

TEST	TIME(MIN)	TEMP.	SLOPE	% OF 01-05 MIN.
1	01-05	25 C	.470	100
	10-14	25 C	.435	93
	20-24	26 C	.458	97
	30-34	26 C	.449	96
	40-44	27 C	.450	96
	50-54	27 C	.424	90
	60-64	28 C	.429	91
2	01-05	27 C	.727	100
	10-14	27 C	.766	105
	20-24	28 C	.700	96
	30-34	27 C	.703	97
	40-44	27 C	.600	82
	50-54	28 C	.636	88
	60-64	28 C	.617	85
3	01-05	26 C	.823	100
	10-14	27 C	.833	101
	20-24	28 C	.849	103
	30-34	28 C	.841	102
	40-44	29 C	.916	111
	50-54	29 C	.925	112
	60-64	29 C	1.006	122

	TEST 1	TEST 2	TEST 3
DATE	4/20/51	4/13/51	4/14/51
START TIME	9:48 A.M.	4:00 P.M.	2:40 P.M.
BAROMETER	29.62"	28.74"	28.92"

TABLE 9

STUDENT NUMBER 7

TEST	TIME(MIN)	TEMP.	SLOPE	% OF 01-05 MIN.
1	01-05	25 C	.541	100
	10-14	25 C	.498	92
	20-24	26 C	.481	89
	30-34	26 C	.479	88
	40-44	27 C	.485	90
	50-54	27 C	.495	92
	60-64	27 C	.453	84
2	01-05	25 C	.498	100
	10-14	26 C	.711	143
	20-24	27 C	.701	142
	30-34	28 C	.662	133
	40-44	28 C	.784	157
	50-54	28 C	.625	126
	60-64	28 C	.648	130
3	01-05	27 C	.905	100
	10-14	28 C	.642	71
	20-24	28 C	.840	93
	30-34	28 C	.814	90
	40-44	29 C	.789	87
	50-54	29 C	.821	91
	60-64	29 C	.788	87

	TEST 1	TEST 2	TEST 3
DATE	4/16/51	4/18/51	4/20/51
START TIME	2:40 P.M.	2:35 P.M.	2:40 P.M.
BAROMETER	29.29"	28.98"	29.54"

TABLE 3

STUDENT NUMBER 7

TEST	SCORE(MIN)	TEMP.	SCORE	% OF 01-05 SCR.
1	01-05	20 D	.641	100
	10-14	35 D	.695	92
	20-24	06 C	.881	86
	30-34	05 C	.479	86
	40-44	27 C	.485	80
	50-54	27 C	.905	82
	60-64	07 C	.453	64
2	01-05	25 C	.460	100
	10-14	80 C	.711	142
	20-24	87 D	.701	142
	30-34	80 C	.802	138
	40-44	25 C	.734	127
	50-54	05 C	.825	120
	60-64	20 C	.862	130
3	01-05	87 C	.503	100
	10-14	25 C	.042	72
	20-24	25 C	.240	52
	30-34	20 C	.814	90
	40-44	20 C	.701	87
	50-54	20 C	.821	81
	60-64	25 C	.708	67

	TEST 1	TEST 2	TEST 3
DATE	4/19/01	4/19/01	4/20/01
START TIME	2:40 P.M.	3:05 P.M.	2:40 P.M.
BAROMETER	29.20"	29.20"	29.06"

TABLE 10

STUDENT NUMBER 8

TEST	TIME(MIN)	TEMP.	SLOPE	% OF 01-05 MIN.
1	01-05	24 C	.454	100
	10-14	25 C	.389	86
	20-24	25 C	.486	107
	30-34	26 C	.380	84
	40-44	26 C	.372	82
	50-54	27 C	.366	81
	60-64	27 C	.398	88
2	01-05	27 C	.490	100
	10-14	28 C	.422	86
	20-24	28 C	.559	114
	30-34	28 C	.685	140
	40-44	28 C	.508	104
	50-54	28 C	.742	151
	60-64	28 C	.686	140
3	01-05	28 C	.567	100
	10-14	29 C	.595	105
	20-24	28 C	.443	78
	30-34	27 C	.611	108
	40-44	27 C	.501	88
	50-54	27 C	.614	108
	60-64	27 C	.497	88

	TEST 1	TEST 2	TEST 3
DATE	4/19/51	4/18/51	4/16/51
START TIME	4:18 P.M.	4:30 P.M.	4:27 P.M.
BAROMETER	29.38"	29.00"	29.32"

TABLE 10

LABORATORY MEASURES OF

TEST	Time/Hours	Temp.	Glass	% of Original
1	01-05	84 C	.484	100
	10-14	20 C	.386	80
	15-19	23 C	.486	101
	20-24	25 C	.340	84
	40-44	28 C	.372	88
	30-34	27 C	.366	91
	50-54	27 C	.309	86
2	01-05	27 C	.490	100
	10-14	28 C	.484	98
	15-19	28 C	.568	114
	30-34	28 C	.695	140
	40-44	26 C	.508	104
	35-34	25 C	.748	151
	50-54	25 C	.696	140
3	01-03	28 C	.547	100
	10-14	29 C	.598	110
	20-24	28 C	.444	78
	30-34	27 C	.811	100
	45-44	27 C	.501	88
	50-54	27 C	.614	100
	60-64	27 C	.497	88

	TEST 1	TEST 2	TEST 3
DATE	4/19/81	4/15/81	4/16/81
START TIME	4:18 P.M.	4:30 P.M.	4:47 P.M.
BAROMETER	29.29"	29.09"	29.34"

TABLE 11

STUDENT NUMBER 9

TEST	TIME(MIN)	TEMP.	SLOPE	% OF 01-05 MIN.
1	01-05	27 C	.510	100
	10-14	27 C	.481	94
	20-24	27 C	.438	86
	30-34	29 C	.500	98
	40-44	29 C	.388	76
	50-54	29 C	.466	91
	60-64	30 C	.456	89
2	01-05	27 C	.555	100
	10-14	27 C	.624	112
	20-24	27 C	.609	110
	30-34	27 C	.623	112
	40-44	28 C	.625	113
	50-54	28 C	.601	108
	60-64	28 C	.644	116
3	01-05	31 C	.704	100
	10-14	32 C	.731	104
	20-24	32 C	.695	99
	30-34	33 C	.739	105
	40-44	33 C	.698	99
	50-54	34 C	.699	99
	60-64	34 C	.664	94

	TEST 1	TEST 2	TEST 3
DATE	4/24/51	4/23/51	5/21/51
START TIME	12:40 P.M.	2:36 P.M.	2:30 P.M.
BAROMETER	29.43"	29.60"	29.18"

Table II

Statistical Summary 4

Class	Variability	Mean	Score	% of Class Mean
1	01-05	27 0	.010	100
	10-14	27 0	.021	34
	20-24	27 0	.032	56
	30-34	27 0	.040	66
	40-44	27 0	.052	76
	50-54	27 0	.060	83
	60-64	27 0	.070	88
2	01-05	27 0	.058	100
	10-14	27 0	.064	112
	20-24	27 0	.070	110
	30-34	27 0	.070	112
	40-44	27 0	.068	118
	50-54	27 0	.071	108
	60-64	27 0	.074	120
3	01-05	27 0	.104	100
	10-14	27 0	.121	104
	20-24	27 0	.130	94
	30-34	27 0	.150	108
	40-44	27 0	.170	82
	50-54	27 0	.184	90
	60-64	27 0	.204	94

	Test 1	Test 2	Test 3
Date	4/24/27	4/28/27	5/23/27
Start Time	12:40 P.M.	2:30 P.M.	1:00 P.M.
Duration	50.40"	52.00"	59.12"

TABLE 12

RECAPITULATION OF SLOPES FOR TEST 1

STUDENT	01-05	10-14	20-24	30-34	40-44	50-54	60-64
1	.430	.434	.450	.459	.549	.474	.460
2	.458	.475	.451	.492	.432	.442	.450
3	.423	.438	.409	.392	.421	.414	.425
4	.439	.502	.449	.446	.458	.402	.426
5	.482	.521	.484	.489	.539	.471	.443
6	.470	.435	.458	.449	.450	.424	.429
7	.541	.498	.481	.479	.485	.495	.453
8	.454	.389	.486	.380	.372	.366	.398
9	.510	.481	.438	.500	.388	.466	.456
"t" value		.210	1.000	.316	.160	.913	1.625

For seven degrees of freedom "t" is 2.365 at 5% level.

TABLE 12

CORRELATION OF SCORES FOR YEAR 1

STUDENT	01-05	10-14	20-24	30-34	40-44	50-54	60-64
1	.460	.454	.450	.434	.349	.474	.460
2	.438	.479	.451	.432	.432	.446	.480
3	.483	.432	.407	.392	.421	.414	.483
4	.439	.309	.449	.446	.432	.402	.486
5	.402	.381	.434	.409	.339	.471	.445
6	.470	.435	.486	.449	.480	.424	.429
7	.341	.409	.421	.479	.406	.439	.433
8	.454	.389	.406	.360	.378	.396	.399
9	.310	.401	.432	.300	.389	.405	.436
"r" value		.470	1.000	.313	.160	.313	1.000

For mean degrees of freedom "t" is 2.365 at 5% level.

TABLE 13

RECAPITULATION OF SLOPES FOR TEST 2

STUDENT	01-05	10-14	20-24	30-34	40-44	50-54	60-64
1	.602	.612	.600	.622	.596	.637	.621
2	.634	.619	.589	.580	.590	.625	.535
3	.575	.519	.492	.528	.496	.551	.475
4	.666	.735	.638	.625	.600	.629	.640
5	.709	.682	.639	.633	.584	.602	.677
6	.727	.766	.700	.703	.600	.636	.617
7	.498	.711	.706	.662	.784	.625	.648
8	.490	.422	.559	.685	.508	.742	.686
9	.555	.624	.609	.623	.625	.601	.644
"t" value		.325	.800	.688	1.862	.963	1.000

Twelve 2.179

For six degrees of freedom "t" is 2.447 at 5% level.

TABLE 12

CORRELATIONS OF SCORES FOR CASE 5

Subject	01-05	11-15	21-25	31-35	41-45	51-55	61-65
1	.902	.812	.800	.833	.844	.887	.921
2	.986	.819	.894	.900	.960	.969	.982
3	.879	.919	.958	.988	.990	.991	.972
4	.864	.758	.894	.956	.900	.939	.964
5	.708	.699	.839	.892	.984	.998	.917
6	.721	.730	.720	.704	.900	.930	.917
7	.660	.712	.706	.882	.764	.950	.948
8	.490	.692	.889	.889	.908	.746	.988
9	.888	.934	.904	.938	.960	.801	.944
"f" Value		.250	.000	.898	1.998	.963	1.000

*Use exp 4 degrees of freedom "f" is 2.812 at 5% level.

TABLE 14

RECAPITULATION OF SLOPES FOR TEST 3

STUDENT	01-05	10-14	20-24	30-34	40-44	50-54	60-64
1	.734	.736	.660	.628	.622	.668	.674
2	.531	.619	.609	.584	.549	.562	.528
3	.718	.703	.669	.689	.689	.767	.839
4	.618	.810	.708	.688	.687	.747	.787
5	.651	.756	.690	.689	.656	.599	.625
6	.823	.833	.849	.841	.916	.925	1.006
7	.905	.642	.840	.814	.789	.821	.788
8	.567	.595	.443	.611	.501	.614	.497
9	.704	.731	.695	.739	.698	.699	.664
"t" value		.388	.098	.020	.158	.237	.433

For seven degrees of freedom "t" is 2.365 at 5% level.

TABLE 14

COEFFICIENTS OF SKEWNESS FOR STAGE X

Treatment	01-06	16-24	25-32	33-40	40-48	49-56	57-64
1	.734	.730	.690	.630	.644	.609	.674
2	.682	.617	.669	.664	.649	.703	.650
3	.716	.703	.669	.639	.699	.787	.860
4	.618	.818	.708	.668	.697	.747	.757
5	.671	.704	.740	.685	.656	.674	.622
6	.693	.679	.649	.647	.719	.829	1.009
7	.743	.661	.640	.674	.759	.842	.788
8	.697	.875	.664	.677	.801	.814	.697
9	.734	.721	.669	.736	.838	.819	.804
"F" ratio	.855	.945	.870	1.156	.857	.855	

The above coefficients of Skewness "F" is Highly at 5% level.

TABLE 15

RECAPITULATION OF PERCENTAGES FOR TEST 1

STUDENT	01-05	10-14	20-24	30-34	40-44	50-54	60-64
1	100	101	105	107	128	110	107
2	100	104	98	107	94	97	98
3	100	104	97	93	100	98	100
4	100	114	102	102	104	92	97
5	100	108	100	101	112	98	92
6	100	93	97	96	96	90	91
7	100	92	89	88	90	92	84
8	100	86	107	84	82	81	88
9	100	94	86	98	76	91	89
"t" value		.455	1.444	.427	.000	1.734	2.061

For seven degrees of freedom "t" is 2.365 at 5% level.

TABLE 15

RECALIBRATIONS OF THERMISTORS FOR ISSUE I

THERMIST	01-09	10-19	20-29	30-39	40-49	50-59	60-69
1	100	101	109	107	129	110	107
2	100	104	96	107	94	87	98
3	100	108	97	93	100	96	100
4	100	114	102	108	104	98	97
5	100	105	100	101	115	106	98
6	100	90	97	96	96	96	91
7	100	95	95	98	90	95	94
8	100	89	107	84	82	91	96
9	100	94	89	90	76	91	99
"t" value	.459	1.444	.427	.000	1.754	8.861	

For seven degrees of freedom "t" is 2.365 at 95% level.

TABLE 16

RECAPITULATION OF PERCENTAGES FOR TEST 2

STUDENT	01-05	10-14	20-24	30-34	40-44	50-54	60-64
1	100	102	100	103	99	106	103
2	100	98	93	91	93	99	84
3	100	90	86	92	86	96	83
4	100	110	96	94	90	94	96
5	100	96	90	89	82	85	95
6	100	105	96	97	82	88	85
7	100	143	142	133	157	126	130
8	100	86	114	140	104	151	140
9	100	112	110	112	113	108	116
"t" value		.626	2.185	1.025	1.947	1.050	1.193

For six degrees of freedom "t" is 2.447 at 5% level.

TABLE 16

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	104	128	100	104	48	108	102
2	100	98	96	82	92	84	94
3	100	92	86	92	96	94	82
4	100	116	98	94	98	96	98
5	130	94	96	88	92	[illegible]	98
6	100	108	98	92	94	88	98
7	100	142	142	138	104	116	120
8	100	98	114	140	106	124	140
9	100	112	132	132	112	108	110
"f" value		.956	2.152	1.038	1.842	1.000	1.160

For 8 d.f. values of f greater than 3.44, P is 0.05 or less.

TABLE 17

RECAPITULATION OF PERCENTAGES FOR TEST 3

STUDENT	01-05	10-14	20-24	30-34	40-44	50-54	60-64
1	100	100	90	86	85	91	92
2	100	117	115	110	103	106	99
3	100	98	93	96	96	107	117
4	100	131	115	111	111	121	127
5	100	116	106	106	101	92	96
6	100	101	103	102	111	112	122
7	100	71	93	90	87	91	87
8	100	105	78	108	88	108	88
9	100	104	99	105	99	99	94
"t" value		.760	.506	.230	.256	.609	.785

For seven degrees of freedom "t" is 2.365 at 5% level.

TABLE 17

CORRELATION OF FACTORIZABLE AND TRUE D

PERIOD	01-05	10-15	20-25	30-35	40-45	50-55
1	100	100	90	96	83	91
2	100	117	118	110	103	109
3	100	98	93	86	96	107
4	100	121	116	111	111	121
5	100	116	100	106	101	93
6	100	101	103	104	111	118
7	100	74	93	90	87	91
8	100	108	94	108	88	104
9	100	104	99	108	99	99
"t" value		.760	.904	.856	.884	.809

For seven degrees of freedom "t" is 2.306 at 5% level.

APPENDIX A

Sample Calculation

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2}}}$$

where $S_1^2 = \frac{1}{N_1 - 1}\left[\Sigma X_1^2 - \frac{(\Sigma X_1)^2}{N_1}\right]$ $\qquad \bar{X}_1 = \frac{\Sigma X_1}{N_1}$

$S_2^2 = \frac{1}{N_2 - 1}\left[\Sigma X_2^2 - \frac{(\Sigma X_2)^2}{N_2}\right]$ $\qquad \bar{X}_2 = \frac{\Sigma X_2}{N_2}$

Test 1

	Slopes		Percentages	
Student	01-05	10-14	01-05	10-14
1	.430	.434	0	1
2	.458	.475	0	4
3	.423	.438	0	4
4	.439	.502	0	14
5	.482	.521	0	8
6	.470	.435	0	-7
7	.541	.498	0	-8
8	.510	.481	0	-6
ΣX	3.753	3.784	0	10
$\bar{X}$	.469	.473	0	1.25
$(\Sigma X)^2$	14.085009	14.3186556	0	100

APPENDIX A

Sample Calculation

$$r = \frac{\sum XY - \frac{\sum X \sum Y}{N}}{\sqrt{\left(\sum X^2 - \frac{(\sum X)^2}{N}\right)\left(\sum Y^2 - \frac{(\sum Y)^2}{N}\right)}}$$

where $\sum X^2 = \sum X^2 - \frac{(\sum X)^2}{N}$ $\left[\sum X^2 - \frac{(\sum X)^2}{N}\right]$ $\sum Y^2 = \sum Y^2 - \frac{(\sum Y)^2}{N}$

$\sum X^2 = \sum X^2 - \frac{(\sum X)^2}{N}$ $\left[\sum X^2 - \frac{(\sum X)^2}{N}\right]$ $\sum Y^2 = \sum Y^2 - \frac{(\sum Y)^2}{N}$

Test I

Subjects	Scores		Percentages	
	01-00	10-19	01-00	10-19
1	.250	.554	0	1
2	.158	.472	0	4
3	.428	.450	0	4
4	.458	.508	0	14
5	.482	.817	0	8
6	.410	.450	0	-4
7	.041	.484	0	-0
8	.010	.402	0	-0
$\sum X$	2.120	3.764	0	10
$\bar{X}$	.424	.643	0	1.50
$(\sum X)^2$	17.880504	14.1760256	0	100

	01-05	10-14	01-05	10-14
$\frac{(\Sigma X)^2}{N}$	1.760626	1.789832	0	12.5
ΣX^2	1.772319	1.797860	0	442.0
S^2	.001670	.001147	0	429.5
$\sqrt{\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2}}$		.019		2.746
$\bar{X}_1 - \bar{X}_2$		.004		1.25
t		.210		.455

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